Body Mass Index in Bengali Adolescents

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We describe a mixed longitudinal analysis of body mass index (BMI) in a group of Bengali adolescents (age 11-17 years) from a middle income family background and compare this against existing national and international data. Healthy school children, comprising of 416 boys and 343 girls were consented for annual repeat measurements of weight, height and pubertal staging between the years 1998 and 2001. The LMS method was used to construct smoothed BMI mean and standard deviation (SD) curves. Bengali adolescents have lower BMI than affluent Indian children and are –1 to –2 SD below US children. BMI increases in adolescence (boys: r = 0.49, p <0.001, girls: r = 0.54, P <0.001) with age but SMR does not have an independent effect on BMI.

Key words: *Adolescents, Body mass index, Mixed longitudinal study.*

BODY mass index (BMI) is a measure of body fat. Though not ideal, it has reasonable correlation(1) with more objective measures of adiposity (*e.g.*, dual energy *X*-ray absorptiometry). A WHO Expert Committee(2) recommends the use of BMI in the community and the use of the National Center for Health Statistics (NCHS) references till local references are developed.

BMI centiles lines rise from 6 years onwards and continue through adolescence(3). Though cross-sectional studies support this trend(4,5), there are few supportive longitudinal studies. BMI in Indian children has been described by a cross-sectional normative survey(4) of affluent children (11,863 boys, 7694 girls) in 1988-1991. Compared to North American children(6), Indian children have lower BMI. A further cross-sectional study(5) of 818 Bengali boys from middle class families in 1982-1983 showed BMI much below NCHS centiles between ages 9 and 16 years.

We sought to investigate if BMI in healthy Bengali middle income adolescents had changed in a decade following the previous studies. We aimed to perform a longitudinal observational study, compare our data against existing standards and construct a smoothed mean (±1, 2 SD) curve from our group of children.

Subjects and Methods

Healthy children of middle income socio-economic standing were consented and recruited from an inner area school in North Kolkata (1200 children between ages 11 to 16 years). This cohort was followed up from 1998 to 2001 and serial annual measurements were undertaken on a designated day. Age was recorded in decimal years. Standing height was measured using a stadiometer by a single trained observer and recorded to the nearest 0.1 cm. Weight was recorded by a

Seca beam balance to the nearest 0.1 kg. These values were converted to body mass index by the formula: BMI = weight in kg/(height in metres)^2. NCHS BMI charts (year 2000) were used to calculate BMI standard deviation scores (SDS). Pubertal staging (Sex Maturity Rating, SMR) was performed using the Tanner method(7). Breast staging in girls and genital staging in boys were chosen to represent SMR.

The distribution of BMI in a population depends on age and tends to be positively skewed. To construct mean curves, we used the LMS method(8) which summarizes the centiles by 3 smooth curves representing skewness (L curve), the median (M curve) and coefficient of variation (S curve). This program uses a penalised maximum likelihood to fit cubic smoothing splines to the L, M and S values. The choice of the smoothing parameters for the L, M and S curves was made on the basis of detrended QQ plots.

Data was analyzed by SPSS 11.5 (Chicago, Illinois) and non-parametric tests used to compare data in two or more groups. Univariate analysis of variance was used to compare non-parametric regression slopes of SMR subgroups in BMI versus age plots. Growth Analyser 2.0 (version 2.0, build 61) software was used for LMS curve fitting.

Results

We recruited 416 boys and 343 girls aged 11-16 years in 1998. These children were followed up –27.2% boys and 31.7% girls were re-measured every year for the next 4 years. The number of children (boys, girls) in each age group were as follows: 11 (123,169), 12 (117, 167), 13 (161, 197), 14 (161, 183), 15 (110, 140), 16 (58, 74), 17 (30, 42). The combined database provided a mixed longitudinal database of BMI measurements in the age range 11 to 17 years.

BMI was converted to SD scores using the NCHS data. The mean (SD) of BMISDS in Bengali children is lowest at –1.8 (1.8) at 11 years and rises to –1.1 (1.2) by age 17 years. All BMI values in Bengalis are –1 to –2 SD outside the mean for US children. Further comparison was made with cross-sectional data of nationally representative affluent children in the same age range. Mean plots (*Figs. 1a* and *1b*) demonstrate higher BMI in Indian affluent adolescents in all ages. Of the Bengali adolescents, girls have higher BMI compared to boys in all age groups except at age 11 years ($p = 0.4$). There is stepwise rise of BMI with age [boys ($r = 0.49$, $P < 0.001$) and girls ($r = 0.54$, $P<0.001$)]. To evaluate if SMR plays an independent role in BMI increment, we plotted BMI for age in SMR subgroups. Though the number of children and R^2 values were small, significant regression lines were present in SMR 2, 3, 4 in boys and SMR 2, 4, 5 in girls. Comparison of regression slopes in these subgroups demonstrated no independent effect of advancing puberty on increasing BMI.

We constructed mean curves (± 1, 2 SD) for BMI in boys and girls (*Figs. 2a* and *2b*). For boys, the effective degrees of freedom (edf) were equal to 5 (M), 3 (S) and 2 (L) and for girls 6, 3 ad 2 respectively. Table I summarises the fitted LMS curves for BMI by age and sex. L values of 1 indicate normality and smaller values represent progressively greater skewness. The M curve is the 0 SD line for BMI. The S curve defines coefficient of variation (CV) and is rather high at 12-13%.

Discussion

There are few studies of anthropometric data in the adolescent age group. It is well known that BMI rises through the teenage years(1) but no longitudinal studies in Indian children demonstrate this. Our study clearly

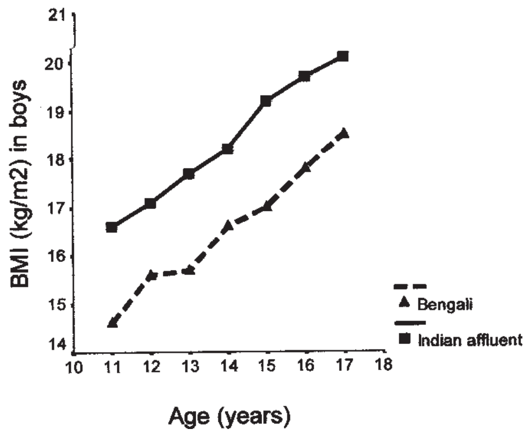

Fig.1a. BMI in middle income Bengali boys (2001) and Indian affluent boys (1991).

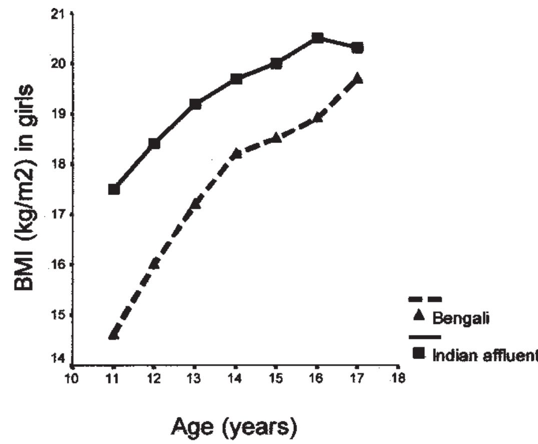

Fig.1b. BMI in middle income Bengali girls (2001) and Indian affluent girls (1991).

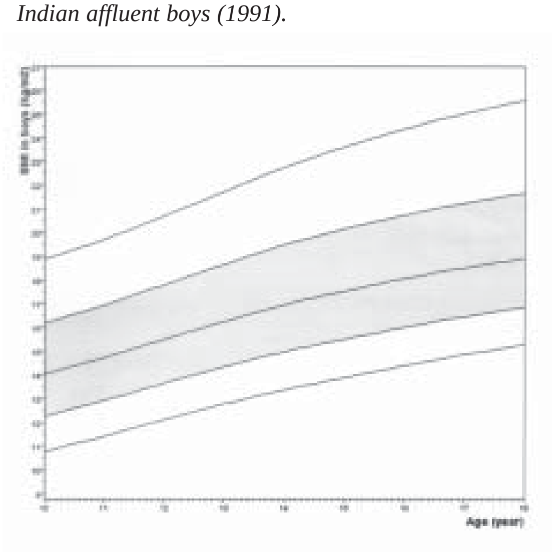

Fig. 2a. BMI smoothed curves in middle income Bengali boys (2001): mean curve is bounded by ± 1, 2 SD.

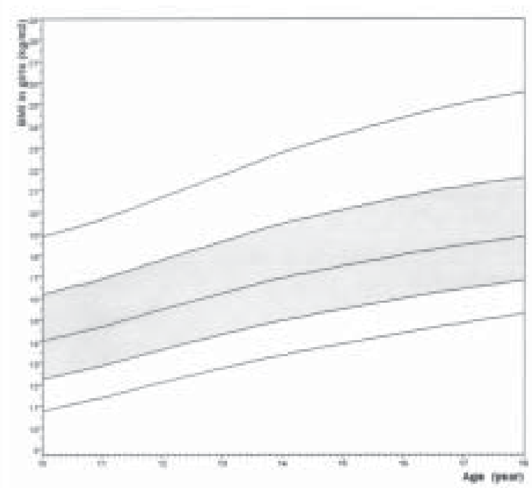

Fig. 2b. BMI smoothed curves in middle income Bengali girls (2001): mean curve is bounded by ± 1, 2 SD.

shows the increasing trend in Bengali boys and girls. Measuring BMI on US centiles (or Indian affluent children) gives unrealistic evidence of thinness(6). It is well known that children of Indian parentage residing in the US have smaller BMI(9) and Bengali middle class boys fare poorly in comparison to Western counterparts(5). Our study demonstrates similar deviation and points to the importance of developing locally based centiles.

We devised mean curves from our group of middle income Bengali adolescents. The numbers of children in each age group (11 to 17 years) are not comparable to some of the larger cross-sectional studies(3). The coefficient of variation in our adolescents appear rather high (12-13%) suggesting wider

TABLE I–*LMS Values for BMI (kg/m2) in Bengali Adolescents*

Age (years)	Boys			Girls		
	L	M	S	L	M	S
11.0	–0.49	14.73	0.136	–0.51	14.71	0.135
11.5	–0.54	15.08	0.134	–0.56	15.07	0.134
12.0	–0.60	15.56	0.133	–0.63	15.56	0.133
12.5	–0.65	15.90	0.132	–0.69	15.90	0.132
13.0	–0.70	16.23	0.132	–0.74	16.23	0.131
13.5	–0.75	16.57	0.131	–0.79	16.57	0.131
14.0	–0.81	16.98	0.131	–0.86	16.99	0.131
14.5	–0.86	17.25	0.131	–0.91	17.25	0.131
15.0	–0.92	17.58	0.130	–0.98	17.56	0.130
15.5	–0.97	17.82	0.130	–1.04	17.81	0.129
16.0	–1.02	18.06	0.129	–1.09	18.05	0.129
16.5	–1.06	18.28	0.128	–1.14	18.27	0.128
17.0	–1.13	18.55	0.127	–1.21	18.53	0.126

dispersion of data due to smaller numbers. However these values are very similar to that of larger data in Dutch children(3) in the same age range, indicating that variability is a feature of adolescence itself.

We used one trained observer to measure height, thereby reducing inter-observer differences. The stadiometer and beam balance were calibrated before use thereby reducing bias from instrumental errors. There remains possible bias in selection of children and staging of puberty. Further, intra-observer variability and precision estimates were not performed. However, BMI is a derived number (a ratio) and therefore unlikely to be altered significantly by minor errors. In fact this is why BMI is an effective epidemiological tool for use in the community.

Though formal dietary intake was not recorded, a rough assessment was made at the medical examination and dietary patterns were found to be similar in all children. All children in the database were healthy at the time of entry. Though the possibility of chronic malnutrition and it sequelae remain(10,11), it is unlikely that the population was "malnourished" enough to skew the data. It is therefore likely that Bengali children are genetically determined to have lower BMI and hence the importance of local data.

A criticism of our study is that we chose children of middle income and not affluent families. Data based on affluent children provide normative data against which the performance of other children is judged. This is important when a section of the population is significantly malnourished. The improved socio-economic situation has reduced severe malnutrition in the community and it is less important to consider affluent children as the

Key Messages

- Boys and girls from Bengali middle income families have lower BMI than affluent Indian or US children
- Bengali adolescent BMI smoothed mean curves may be useful tools in the local population

norm. A "middle of the road" approach is therefore more appropriate, as that practiced in the developed nations like the United States, United Kingdom and Japan.

On national cross-sectional data, BMI appears to be similar in the same SMR subgroup. With advancing age and pubertal hormonal changes, fat (and muscle mass) is deposited to give rise to higher BMI. It is therefore possible that SMR subgroups are independent variables in predicting BMI. We however could not demonstrate an influence of advancing SMR on increasing BMI. From a practical standpoint, SMR is subjective and prone to error when performed by non-experienced individuals.

BMI is a derived measurement and does not provide objective evidence of adiposity. It does not discriminate between fat mass and lean body mass. It is seen as an abstract index of nutritional status than as a measure of body composition(12). Though a reasonable tool for community use(2), we must exercise caution in laying too great an emphasis on its interpretation. The real importance of BMI is in documenting emerging trends with economic prosperity and energy-dense food intake to correlate with an increase in insulin resistance(13,14).

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Contributors: IB analysed the data and wrote the manuscript. NG contributed in data collected and edited the paper. SB was involved in data collection and drafting. HNS was the study director for concept, design and execution. DM was the chief investigator responsible for design, planning and editing.

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REFERENCES

1. Pietrobelli A, Faith MS, Allison DB, Gallagher D, Chiumello G, Heymsfield SB. Body mass index as a measure of adiposity among children and adolescents: a validation. J Pediatr 1998; 132: 204-210.
2. Physical Status: The use and Interpretation of Anthropometry - Report of a WHO Expert Committee, Geneva World Health Organization. 1995; pp. 263-308.

3. Frederiks AM, Van Buuren S, Wit JM, Verloove-Vanhorick SP. Body index measurements in 1996-97 compared with 1980. Arch Dis Child 2000; 82:107-112.

4. Agarwal KN, Saxena A, Bansal AK, Agarwal DK. Physical growth assessment in adolescence. Indian Pediatr. 2001 38: 1217-1235.

5. De Onis M, Dasgupta P, Saha S, Sengupta D, Blossner M. The National Center for Health Statistics reference and the growth of Indian adolescent boys. Am J Clin Nutr 2001, 74: 248-253.

6. Rosner B, Prineas R, Loggie J, Daniels SR. Percentiles for body mass index in US children 5 to 17 years of age. J Pediatr 1998; 132: 211-222.

7. Tanner JM: Growth at Adolescence, 2nd ed. Oxford, England, Blackwell Scientific Publications, 1962.

8. Cole TJ, Green PJ. Smoothing reference centile curves: the LMS method and penalised likelihood. Stat Med 1992; 11: 1305-1319.

9. Rosner B, Prineas R, Loggie J, Daniels SR. Percentiles for body mass index in US children 5 to 17 years of age. J Pediatr 1998; 132: 211-222.

10. Gupta RK, Mittal RD, Agarwal KN, Agarwal DK. Muscular sufficiency, Serum protein, enzymes and bioenergetic studies (31-phosphorus magnetic resonance spectroscopy) in chronic malnutrition. Acta Pediatr 1994; 83: 327-331.

11. Agarwal KN, Agarwal DK, Upadhyay SK. Sequelae of early undernutrition on reaction time of rural children at 11-14 years. Indian J Med Res 1998; 107:98-102.

12. Wells JCK. Measurement: A critique of the expression of paediatric body composition data. Arch Dis Child, 2001; 85: 67-72.

13. Yajnik CS. Early life origins of insulin resistance and type 2 diabetes in India and other Asian countries. J Nutr 2004; 134: 205-210.

14. Hales CN, Barker DJ. Type 2 (non-insulin-dependent) diabetes mellitus: the thrifty phenotype hypothesis. Diabetologia. 1992; 35: 595-601.